Plans and Cost of Elevation Of a Portion of the Tracks Of the H. & N. Railway

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A Thesis Presented By

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and

L. B. Young

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of

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PLANS, SPECIFICATIONS, AND COST OF ELEVATION OF A PORTION OF THE TRACKS OF THE H. & N. RY.

This thesis contains the general design of all structures required for the elevation of 3.34 miles of the tracks of the H. & N. RY. The cost of the construction is figured in detail, but no attempt has been made to treat this subject from the economical point of view.

The tracks are a portion of those of the H. & N. RY. in the city of Chicago. They extend from Avenue A to the Calumet River, running from northwest to southeast. As only a portion of the right of way has been taken for this thesis, it has been considered necessary to start the tracks from the present level on a grade of about 0.8 per cent from a point about one thousand, six hundred and sixty (1660) feet northwest of Avenue A up to Avenue A, where the elevation of the base of rail will be 21.0 feet above city datum. The right of way of the H. & N. RY. is one hundred feet wide, and is bounded on the north side by the right of way of the L. R. & B. RY., whose tracks are to be elevated at the same time as those of the H. & N. RY.

The ordinances of the city of Chicago require an elevation of the base of rail of 21.0 feet above city datum from Avenue A to a point ten thousand, three hundred (10,300) feet southeast of Avenue A, and continuing in a southeasterly direction from this point on an ascending grade of 0.3 per cent to a point

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thirteen thousand, nine hundred (13,900) feet southeast of Avenue A where an elevation of the base of rail of 31.8 feet above city datum shall have been attained, and continuing in a southeasterly direction from this point across the right of way of the B. N. & C. RY. for a distance of about eighty (80) feet, with the same elevation of the base of rail, and continuing from this point in a southeasterly direction on a descending grade of 0.3 per cent till the elevation of the base of rail becomes 21.0 feet above city datum.

The main difficulty to be met with in connection with track elevation is the maintenance of traffic with no delay whatever, during the time the construction work is going on. This requires that at least two tracks shall be kept open for traffic. The method of carrying on this construction, as outlined near the end of this article, is such that two tracks may be kept open to traffic and no trains will be delayed. Owing to the fact that the width of the right of way is one hundred feet, matters have been simplified considerably so that the construction can be carried on quickly.

Track elevation divides itself into two processes: namely, (1) the construction of the subways at street and railway intersections, and (2) the elevation of the tracks between the intersecting streets and railways. The first process requires at the street intersections, the construction of abutments and piers to support the steel superstructure; the paving of the street in the subway after grading has been done; the building of catch-basins,

connections to sewers in the subway, manholes, curbing, and cement sidewalks; and the placing of the steel superstructure. The second process requires the placing of filling sand, the laying of tracks, and the placing of ballast.

Filling sand may be obtained at a sand pit along the line of the H. & N. RY., at a distance of about thirteen miles from the portion of tracks considered in this thesis. The H. & N. RY. has its own tracks into the pit for the purpose of loading sand into cars.

All abutments, retaining walls, abutment foundations, retaining wall foundations, piers, curbing, and cement sidewalk are to be built of Portland cement concrete, specifications for the same being submitted with this thesis. The curbing, cement sidewalks, catch-basins and their connections to sewers, manholes, and street paving are to be built according to the specifications of the city of Chicago, which are submitted with this thesis. All streets are to be paved with vitrified paving bricks placed on a foundation as called for in the specifications. The crown of the street shall have an elevation above city datum as specified in the ordinances of the city of Chicago. This elevation of the crown of the streets shall extend from the north property line of the H. & N. RY. to the south property line of the H. & N. RY. and from this point shall ascend on a grade of 3.5 per cent till the present grade of the street is reached.

The tracks of the B. N. & C. RY., and all streets, with the exception of Avenue C, intersect the tracks of the H. & N. RY.

at an angle of 45°. Avenue C intersects the tracks of the H. & N. RY. at an angle of 90°. The distance between the face of the abutments where the H. & N. RY. crosses the B. N. & C. RY. will be fifty-two (52) feet, measured transversely to the tracks of the B. N. & C. RY. This will make the distance between the abutments, measured along the tracks of the H. & N. RY., seventy-three and one-half (73.5) feet. The tracks of the H. & N. RY. will be carried across the tracks of the B. N. & C. RY. by a through plate girder with a span of seventy-eight (78) feet. Four tracks will be carried across, requiring five girders. The distance between the face of the abutments at Avenues B, C, D, and First, Second, and Third Streets, measured transversely to the street, will be sixty (60) feet. This will make the distance between the abutments, measured along the tracks of the H. & N. RY., eighty-four and eight tenths (84.8) feet. At Avenue A the distance between the face of the abutments will be one hundred (100) feet, measured transversely to the street, or a distance between the abutments, measured along the tracks of the H. & N. RY., of one hundred and forty-one and four tenths (141.4) feet. Four tracks will be carried across each street, as stated below. At Avenue A there will be three spans of through plate girders, five girders being required for each span. The two end spans will each have a length of twenty-seven (27) feet, one end resting on the abutments and the other end resting on posts placed near the curb line of the street. The middle span across the roadway will have a length of eighty-nine and seventy-five hun-

dredths (89.75) feet. At Avenue B, First, and Second Streets there will be three spans of through plate girders, each requiring five girders. The two spans across the sidewalks will each have a length of thirteen and one-half (13.5) feet, and the span across the roadway will be sixty-one and one-half (61.5) feet. At Avenues C, D, and Third Street there will be three spans of deck plate girders, eight girders being required for each span. At Avenue D and Third Street the spans will have the same length as those spans at Avenue B and First and Second Street. At Avenue C there will be two spans, each having a length of nine and one-half (9.5) feet, and one span forty-one and one-half (41.5) feet long.

The floor system of all through plate girders will be built up of 12-inch 50-pound I-Beams, spaced fifteen (15) inches apart, center to center of webs. This flooring is to be made waterproof by means of Portland cement concrete.

The floor system of all deck plate girders will be built up of 9-inch 35-pound I-Beams, spaced twelve (12) inches apart, center to center of webs. On top of these I-Beams is to be placed a reinforced concrete slab, which will be waterproof.

Theodore Cooper's, "General Specifications for Steel Railroad Bridges and Viaducts", will govern the kind of materials and workmanship required in constructing and erecting all steel superstructures.

Specifications.

Specifications to be followed in the construction of abutments, retaining walls, abutment foundations, retaining wall foundations, and piers of Portland cement concrete.

1.CEMENT. The cement shall be of first-class Portland cement of reputable brand, which shall conform in all respects to the cement specifications herewith annexed. The cement shall be delivered in cars and unloaded from the same only when to be put to immediate use. It shall be so placed in cars as to permit of easy access for inspection and identification of each shipment. A sufficient quantity shall be kept on hand at all times so that the Engineer-in-charge may have opportunity and time to make tests sufficient to determine its quality. At least twelve days shall be allowed for inspection and necessary tests.

2. SCREENINGS. The screenings shall consist of pieces of limestone which will pass a 1/4-inch screen.

3. BROKEN STONE. The broken or crushed stone shall consist of pieces of limestone which will pass a 2-inch screen.

4. WATER. The water shall be free from acids or strong alkalis.

5. PROPORTIONS. The proportions of the raw materials for the concrete shall be exactly determined from time to time by the Engineer-in charge in accordance with the relative coarseness of the aggregate so as to attain as dense a concrete as is consistent with the terms of the specifications which follow.

The proportion of cement to screenings to stone will be 1:3:6, which will require one barrel (376 lbs.) cement, 0.44

cubic yard limestone screenings, and 0.88 cubic yard broken stone per cubic yard of concrete. The cement is to be measured as packed by the manufacturer, and the limestone screenings, and the broken stone are to be measured as shoveled loosely into an ordinary stone measuring box or barrel.

6. HAND MIXING. If it becomes necessary at any time to mix a portion of the concrete by hand, the cement and aggregate shall be mixed and the water added on a tight platform enough to provide space for the partially simultaneous mixing of two batches of not more than one cubic yard each. The limestone screenings and cement shall be spread in thin layers and mixed dry until of uniform color. This mixture may be placed upon the layer of stone, or the stone shoveled upon it before adding the water, or it may be made into a mortar before spreading it with the broken stone. In the former method the materials shall be turned at least three times,-in addition to the mixing of the limestone screenings and cement already mentioned, the water being added on the first turning,- and in addition to the shoveling from the platform to place or into the vehicle for transportation In the latter method, that is, if the limestone screenings and cement are first made into a mortar, the mass of mortar and stone shall be turned at least twice. Whatever the method employed is, the number of turnings shall be sufficient to produce a resulting loose concrete of uniform color and appearance, with the stones thoroughly incorporated into the mortar and the consistency uniform throughout.

7. MACHINE MIXING. If the concrete is mixed in a machine mixer, a machine shall be selected into which the materials, including the water, can be precisely and regularly proportioned, and, which will produce a concrete of uniform consistency and color with the stones and water thoroughly mixed and incorporated with the mortar.

8. CONSISTENCY. A medium or quaking mixture of a tenacious, jelly-like consistency, which quakes on ramming, shall be used for ordinary mass concrete, such as foundations, heavy walls, piers, and abutments.

9. PLACING. Concrete shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients, or in cases where such separation inadvertently occurs, the concrete shall be remixed before placing. Each layer in which the concrete is placed shall be of such thickness that it can be incorporated with the one previously laid. Concrete shall be used so soon after mixing that it can be rammed or puddled in place as a plastic, homogeneous mass. Any which has set before placing shall be rejected. When placing fresh concrete upon an old concrete surface, the latter shall be cleaned of all dirt and scum or laitance, thoroughly wet. Noticeable voids or stone pockets discovered when the forms are removed shall be immediately filled with mortar mixed in the same proportions as the mortar in the concrete.

10. EXPOSED FACES. Faces exposed to view shall be made smooth by thrusting a spade or chisel through the concrete close

to the form to force back the large stones and prevent stone "pockets".

11. FREEZING WEATHER. No concrete, except that laid in large masses, or heavy walls having faces whose appearance is of no consequence, shall be exposed to frost until hard and dry. Materials employed in mass concrete in freezing weather shall contain no frost. Surfaces shall be protected from frost. Portions of surface concrete which have frozen shall be removed before laying fresh concrete upon them.

12. FORMS. The timber for the forms and the design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For exposed faces the surface next to the concrete shall be dressed. Forms shall be sufficiently tight to prevent the loss of cement or mortar. They shall be thoroughly braced or tied together so that the pressure of the concrete, or the movement of men, machinery, or materials shall not throw them out of place. Forms shall be left in place until, in the judgment of the Engineer-in-charge, the concrete has attained sufficient strength to resist accidental thrusts and permanent strains which may come upon it. Forms shall be thoroughly cleaned before being used again.

13. GENERAL REQUIREMENTS. Imperfect work ,or materials, or work or materials which may become damaged from any cause before its acceptance, shall be properly replaced to the satisfaction of the Engineer-in-charge.

Foremen in charge of men who are mixing and placing concrete

shall be skilled in concrete mixing, and they shall receive and obey orders from the Engineer-in-charge.

The specifications for the Portland cement to be used in the concrete for abutments, retaining walls, abutment foundations, retaining wall foundations, and piers, are as follows:

1.PACKAGES. Cement shall be packed in strong cloth or canvas sacks. Each package shall have printed upon it the brand and name of the manufacturer. Packages received in broken or damaged condition may be rejoined or accepted as fractional packages.

2. WEIGHT. Four bags shall constitute a barrel, and the average net weight of the cement contained in one bag shall not be less than 94 lbs., or 376 pounds per barrel. A cement bag may be assumed to weigh one pound. The weights of the separate packages shall be uniform.

3. REQUIREMENTS. Cements failing to meet the seven day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

4. TESTS. All tests shall be made in accordance with the methods proposed by the "Committee on Uniform Tests of Cement" of the American Society of Civil Engineers, presented to the Society January 21st, 1903, and amended January 20th, 1904, with all subsequent amendments thereto.

5. Sampling. Samples shall be taken at random from sound packages, and the cement from each package shall be tested separately.

6. The acceptance or rejection shall be based on the following requirements:-

7. DEFINITION OF PORTLAND CEMENT. This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture, properly proportioned, of argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination.

8. SPECIFIC GRAVITY. The specific gravity of the cement thoroughly dried at 100° Centigrade shall be not less than 3.10.

9. FINENESS. It shall leave by weight a residue of not more than 8 per cent on the No. 100 sieve, and not more than 25 per cent on the No. 200 sieve.

10. TIME OF SETTING. It shall develop initial set in not less than 30 minutes, but must develop hard set in not less than one hour nor more than ten hours.

11. TENSILE STRENGTH. Briquettes one inch square in section shall attain at least the following tensile strengths, and shall show no retrogression within the periods specified:-

Neat Cement.

Age.	Strength.
24 hours in moist air	175 lbs.
7 days (1 day in air, 6 days in water)	500 " .
28 days (1 day in air, 27 days in water)	600 " .

One Part Cement, Three Parts Standard Sand.

Age.	Strength.
7 days (1 day in moist air, 6 days in water)	150 lbs.
28 days(1 day in moist air,27 days in water)	200 " .

12. SOUNDNESS OR CONSTANCY OF VOLUME. Pats of neat cement about three inches in diameter, one-half inch thick at the center and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature, and observed at intervals for at least 28 days.

(b) Another pat is kept in water, maintained as near 70° Fahrenheit as practicable, and observed at intervals for at least 28 days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

These pats to satisfactorily pass the test or requirements shall remain firm and hard, and show no signs of distortion, checking, cracking, or disintegration.

13. SULPHURIC ACID AND MAGNESIA. The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of Magnesia (MgO).

SPECIFICATIONS

of

City of Chicago.

The following specifications for the materials and construction of manholes, catch-basins, curbing, cement sidewalk, and vitrified brick paving are extracts from the city specifications. The portion of each set of specifications submitted is sufficient for all the construction of such work as will be necessary.

The specifications for manholes and catch-basins are as follows:-

Manholes.

All manholes are to be circular in section and three feet internal diameter. They are to be built with two rings of brick, giving a thickness of eight inches to the wall. The bricks in the inside ring are to be set vertically. The outer ring may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used.

On sewers three feet in diameter and greater the manholes shall be supported by the arch invert of the sewer without additional foundation. On sewers less than three feet in diameter the invert of the sewer through the manholes shall be built of two rings of brick and on each side thereof shall be built a solid brick foundation twelve inches thick, making the entire foundation four feet and six inches in diameter.

The top of the manhole is to be two feet in diameter, being

drawn in by means of six header courses, the diameter being decreased two inches for each course, and an iron cover set thereon. On unpaved streets, the tops of the covers of the manholes are to be at the surface of the streets; on paved streets, one-half inch lower.

Catch-Basins.

All catch-basins are to be circular in section and four feet in internal diameter. They are to be built of two rings of brick upon a floor of two-inch pine plank closely jointed. The bricks in the inner ring (excepting the top and bottom header courses) are to be set vertically. The outer ring may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used. The brick work shall be seven feet two inches deep; the top of the catch-basins shall be two feet in diameter, being drawn in by means of eight header courses, the diameter being decreased three inches for each course, a top header course, being laid flush with the course below and an iron cover set thereon.

The catch-basins are to be connected to the sewer with nine-inch pipe and trapped with nine-inch half-traps, the bottom of the traps to be set three feet and six inches above the floor of the basin.

The top of the cover shall be set at the grade required.

Covers.

All covers used shall be of good quality of cast iron, the curb shall weigh not less than 350 pounds and the lid shall weigh not less than 120 pounds, and shall be of the same size

and pattern as iron covers now in use by the Bureau of Sewers, in the City of Chicago, provided that if the catch-basins are built in the parkways, lighter covers may be used weighing not less than 140 pounds.

Bricks.

The bricks shall be the best quality for the purpose for which they are intended, uniform in quality, sound and hard burned, free from lime and cracks, and to have a clear ringing sound when struck, whole and with edges full and square, and of standard dimensions; they shall be of compact texture, and after being thoroughly dried and immersed in water for twenty-four hours shall not absorb more than 15 per cent in weight of water.

Cement.

The cement shall be fresh made, of some satisfactory and reliable brand, and of such quality and uniformity as has been demonstrated by the Board of Local Improvements of Chicago, to be of superior quality and thoroughly adapted to the construction of sewers and similar work, and shall be approved by the engineer.

Natural cement shall be so finely ground that 80 per cent of the whole will pass through a sieve of 100 meshes to the lineal inch, and when treated in the usual manner for tensile strength, shall give results comparing favorably with the best brands of American Natural Cement. The cement, when tested in the usual manner, shall take initial set in not less than 12 minutes.

Mortar.

The mortar for the brick work shall be made by carefully measuring and thoroughly incorporating one part of natural cement with two parts of clean, sharp sand in dry state, mixed with clean water to the proper consistency, and shall be used while fresh, and the use of mortar which has set and then been retempered will not be allowed.

The specifications for the combined curb and gutter are as follows:-

In making the combined curb and gutter Portland cement shall be used and ordinarily will be subjected to the following inspection and tests:

Fineness. It shall be so ground that ninety-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness. It shall meet the requirement of the "Boiling" test.

Setting. The cemtn when mixed with twenty (20) per cent of water, by measure, shall take initial set in not less than forty-five (45) minutes.

Strength. Briquettes, one (1) inch square in section, shall develop the following ultimate tensile strngth:
Neat- one day in air and six (6) days in water, 400 pounds.
One (1) part cement to two (2) parts fine granite screenings-one day in air and six days in water, 300 pounds; and shall show a

gradual increase in strength of fifteen (15) per cent at the end of twenty-eight (28) days.

Samples of cements which it is proposed to use in the work, shall be submitted to the Board of Local Improvements in such quantities and such time and place as to make all the required tests.

All cement to be used in the combined curb and gutter must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as may be directed.

The granitescreenings used in making the concrete shall be clean, dry, free from dust, loam and dirt, and when delivered on the street shall be deposited on flooring, and kept clean until used.

The crushed granite shall be clean, free from dust and dirt, broken so as to measure not more than one (1) inch in any dimension and when delivered on the street shall be deposited on a flooring and kept until used.

The granite combined curb and gutter shall be constructed at the established grade and in a continuous line on each side of the street, thirty (30) feet from and parallel with the center line thereof at Avenue A and twenty (20) feet from and parallel with the center line thereof at Avenues B, C, D, and at First, Second, and Third Streets. The combined curb and gutter shall rest on a foundation of cinders which must be six (6) inches in

thickness after being thoroughly flooded and compactly rammed to an even surface.

The curb and gutter shall be made of concrete formed by intimately mixing one (1) part of cement with two (2) parts of fine granite screenings; to this mixture shall be added four (4) parts of crushed granite and the whole thoroughly mixed together after which just sufficient water to wet the mass shall be added, so that when it is rammed in place a film of moisture shall appear on top. All exposed surfaces shall be covered with a finishing coat of mortar three-eighths (3/8) inch in thickness composed of one part of the cement thoroughly mixed with one and one-half (1-1/2) parts of the fine granite screenings. Before the concrete sets, the curb and gutter shall be cut into sections not exceeding six (6) feet in length.

The gutter flag must be eighteen (18) inches wide and five (5) inches thick; the curb must be seven (7) inches thick through out, except at the upper face corner, which is to be rounded to a radius of one and one-half (1-1/2) inches. The height of the curb above the gutter flags will be twelve inches.

The specifications for the vitrified brick paving are as follows:-

Preparation of the Sub-Grade.

Where filling is required it shall be of earth or cinders, free from animal or vegetable matter, and shall be deposited in layers of not more than two (2) feet in thickness, and shall be thoroughly compacted.

All necessary filling to bring the street to sub-grade and to properly back-fill the curb, shall be deposited on the street before any curb is set.

Where cutting is required the earth must be excavated to such depth as may be necessary to bring the roadway to the proper sub-grade after having been thoroughly compacted.

The roadway shall be brought to sub-grade by cutting or filling as may be necessary; said sub-grade shall be eleven and one-half (11-1/2) inches below and parallel with the top of the finished pavement after having been thoroughly compacted and secured from further settlement by flooding, ramming or rolling, or all, as may be deemed necessary.

Concrete Foundation.

On the sub-grade as above prepared shall be laid a foundation of Portland cement concrete to a uniform thickness of six (6) inches.

Cement.

In making the concrete, Portland cement shall be used and will ordinarily be subjected to the following inspection and tests:

Fineness. It shall be so ground that ninety-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness. It shall meet the requirements of the "Boiling" test.

Setting. The cement when mixed with twenty (20) per cent of water, by measure, shall take initial set in not less than forty-five minutes.

Strength. Briquettes, one (1) inch square in section, shall develop the following ultimate tensile strength:
Neat-one day in air and six (6) days in water, 400 pounds.
One (1) part cement to three (3) parts sand as hereinafter specified, one (1) day in air and six (6) days in water, 175 pounds; and shall show a gradual increase in strength of fifteen (15) per cent at the end of twenty-eight (28) days.

Samples of the cement which it is proposed to use in the work, shall be submitted to the Board of Local Improvements in such quantities, and at such time and place, as will enable it to make all required tests.

All cement to be used in the concrete foundation must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as directed.

Sand.

The sand used in making the concrete shall be clean, dry, free from dust, loam, and dirt, of sizes ranging from one-eighth (1/8) inch down to the finest, and in such proportion that the

voids as determined by saturation shall not exceed thirty-three (33) per cent of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot.

No wind-drifted sand shall be used.

The sand when delivered on the street shall be deposited on flooring and kept clean until used.

Crushed Stone.

The crushed stone used in making the concrete shall be of the best quality of limestone, clean, free from dirt, broken so as to measure not more than two (2) inches and not less than one (1) inch in any dimension.

The stone when delivered on the street shall be deposited on flooring and kept clean until used.

Mixing and Laying of Concrete.

The concrete shall be mixed on movable tight platforms of iron of such size as shall accomodate the manipulations hereinafter specified.

The cement, sand and stone shall be mixed in the following proportions: One (1) part of cement, three (3) parts of sand and seven (7) parts of crushed stone. The sand and cement shall be thoroughly mixed, dry, to which sufficient water shall be added and then made into a stiff mortar. The crushed stone shall then be immediately incorporated in the mortar and the mass thoroughly mixed, adding water from time to time as the mixing progresses, until each particle of stone is covered with mortar.

The concrete shall be removed from the platform with shovels

and deposited in a layer on the roadway in such quantities, after being rammed in place, it shall be of the required thickness and the upper surface shall be true and smooth and five and one-half (5-1/2) inches below and parallel with the top of the finished pavement.

During the progress of the work the sub-grade must be kept moist.

The concrete shall be sprinkled so as to prevent checking in hot weather, and shall be protected from injury at all times, and shall lay at least seven (7) days before being covered with the wearing surface, or a longer time if deemed necessary.

Sand Cushion.

Upon the concrete foundation shall be spread a layer of sand of such quantity as to insure, when compacted, a uniform thickness of one (1) inch.

On surfacing said layer of sand guides and templets shall be used as directed.

Wearing Surface.

Upon the layer of sand as above specified shall be placed the brick of such quality and in such manner as hereinafter specified.

Quality of Bricks.

The brick to be used shall be of the best quality of vitrified paving brick. Salt glazed bricks will not be received.

The dimensions of the brick used shall be the same throughout the entire work in any particular case, and shall be not less

than eight (8) inches in length, four (4) inches in depth, and two and one-half (2-1/2) inches in thickness, rounded edges to a radius of one-quarter (1/4) of an inch.

Said brick shall be of a kind known as repressed vitrified paving brick and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime and other impurities, shall be as nearly uniform in every respect as possible, shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness and thoroughly vitrified so as to make a homogeneous mass.

The bricks shall be free from all laminations caused by the process of manufacture, and free from fire cracks of checks of more than superficial character or extent.

A specimen brick shall be submitted to a "water absorption" test, and if such brick show a water absorption exceeding three (3) per cent of their weight when dry, the same shall be rejected Such "water absorption" test shall be made by the Board of Local Improvements of the City of Chicago, in the following manner, to-wit: Not less than three (3) bricks shall be broken across, thoroughly dried, and then immersed in water for seventy-two (72) hours. The absorption shall then be determined by the difference between the weight dry and the weight at the expiration of said seventy-two (72) hours.

Twenty or more bricks shall also be furnished for submission to the " abrasion"test by the Board of Local Improve-

ments. Such test shall be made in the following manner, to-wit: Such specimen brick or a sufficient number to fill fifteen (15) per cent of the volume of the rattler shall be submitted to a test for one hour in the machine known as the "Rattler", which shall measure twenty (20) inches in length and twenty-eight (28) inches in diameter, inside measurement, shall be revolved at the rate of thirty (30) revolutions per minute. If the loss of weight by abrasion during such test shall exceed twenty (20) per cent of the original weight of the brick tested, then such brick shall be rejected.

All brick shall have a specific gravity of not less than two and one-tenth (2-1/10), as determined by the formula- specific gravity equals $\frac{W}{W'-W''}$; where W equals weight of brick dry W' equals weight of brick afeter being immersed in water for seventy-two (72) hours, and W"equals weight of brick in water.

How Laid.

All brick shall be delivered on the work in barrows, and in no case will teams be allowed on the street before the wearing surface is rolled.

Broken bricks can only be used to break joints in starting courses and in making closures, but in no case shall less than half a brick be used.

The bricks shall be laid on edge, close together, in straight lines across the roadway, between gutters and at right angles to the curbs and perpendicular to the grade of the street.

The joints shall be broken by a lap of not less than three

(3) inches.

The bricks when set shall be rolled with a roller weighing not less than five (5) tons until the bricks are well settled and made firm. Or, the bricks, when set, shall be thoroughly rammed two or three times. The ramming to be done under a flatter, with a paving rammer weighing not less than thirty (30) pounds, the iron of the rammer face in no case to come in contact with the pavement.

After rolling and ramming, all broken brick found in the pavement must at once be removed and replaced by sound and perfect brick.

Pitching or Grouting and Top Dressing.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the brick shall be completely filled with a paving pitch which is the direct result of the distillation of "straight run" coal tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280° Fahrenheit.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the bricks shall be filled with a cement grout filler composed of limestone 65 per cent, furnace slag 25 per cent and potters' clay 10 per cent to be made as follows: The above mate-

rials in the proportions stated shall be mixed together and ground into an impalpable powder, and then burned in kilns until reduced clinker after which it shall again be ground into an impalpable powder. Equal porions of said grout and clean sharp sand shall then be thoroughly mixed, and sufficient water added to bring the mixture to such a consistency as will allow it to run to the bottom of the joints between the brick. After said joints are filled to the top, the surface shall be finished off smoothly with steel brooms.

After the spaces between the brick have been filled with the pitch or grout as above specified, the surface of the pavement shall then receive a one-half (1/2) inch dressing of sand, spread evenly over the whole surface.

Where cement grout is used as a filler the pavement must be kept clear of traffic for a period of four (4) days after the application thereof.

The following are the specifications for Portland cement concrete sidewalks:

Foundation.

Soft and spongy places not affording a firm sub-foundation must be dug out and refilled with earth, cinders or other material equally as good for filling purposes, thoroughly compacted by flooding and tamping. Wherever the natural surface of the ground is not sand free from loam, the sidewalk space shall be excavated or filled, as may be necessary, and brought to a sub-grade fourteen (14) inches below the final grade. Upon this sub-foundation shall be placed a layer of clean cinders, or material equally as good for foundation purposes, thoroughly flooded and rammed perfectly solid, and brought to a grade five (5) inches below and parallel with the top of the completed sidewalk. In interpreting these specifications, sand, gravel, crushed stone, or any material of a like character, free from animal, vegetable matter, will be considered "equally as good" as cinders for foundation purposes. Wherever the natural surface of the ground is sand and at grade, no other filling will be required, Wherever filling is required in preparing the sub-foundation, it shall be of earth, cinders or other material equally as good for filling purposes, free from animal or vegetable matter, and shall be deposited in layers of not more than two (2) feet in thickness, except where clay filling is used, then said layers shall not be more than one (1) foot in thickness, each layer to be thoroughly compacted by flooding or tamping before the succeeding layer is

put on. All filling to be done in such a manner as to leave a berm of one (1) foot on each side of and flush with the top of the completed walk, and shall slope to the surface of the ground at the rate of one and one-half (1-1/2) feet horizontal to one (1) foot vertical.

Portland Cement.

The Portland cement used in the construction of the sidewalks will be subject to the following inspection and tests:

Fineness: It shall be so ground that ninety-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch, made of wire cloth, No. 40 wire, Stubbs' gauge.

Soundness: It shall meet the requirements of the following boiling test: A pat of neat cement, three and one-half (3-1/2) inches in diameter, one-half (1/2) inch in thickness at the center and tapering to a feather edge, having been made on glass, and which has remained in air twenty-four (24) hours protected by a damp cloth, together with broken briquettes of neat cement, which have remained in air one (1) day and immersed in water six (6) days, shall, after being submitted to the action of steam four (4) hours and then immersed in boiling water four (4) hours, show no checking, warping or swelling.

Setting: The cement when mixed with twenty-eight (28) per cent of water, by weight, shall take initial set in not less than forty-five (45) minutes as determined by the Gilmore needle.

Strength: Briquettes shall develop the following ultimate

tensile strengths per square inch of section: Neat- one day in air and six (6) days in water, 500 pounds. One (1) part cement to three (3) parts torpedo sand or limestone screenings, one (1) day in air and six (6) days in water, 200 pounds; and shall show a gradual increase in strength of twenty (20) per cent at the end of twenty-eight (28) days.

All cement must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer, and shall be thoroughly protected until used. No damaged, short weight package or lumpy cement will be allowed.

Sand.

The sand to be used in making the concrete shall be known as "Torpedo", and must be clean, dry, free from dust, loam and dirt, and of sizes ranging from one-eighth (1/8) inch down to the finest, in such proportions that the voids, as determined by saturation, shall not exceed thirty-three (33) per cent of the entire volume, and it shall weigh not less then one hundred (100) pounds per cubic foot. No wind-drifted sand shall be used.

The sand shall be delivered on the street, shall be deposited on flooring and kept clean until used.

Stone.

The stone used in making the concrete shall be of the best quality of limestone, or stone equally as good for concrete purposes, or washed gravel, all of which shall be free from dust, loam or dirt or other foreign substances; and of such size measuring not less than one-fourth (1/4) inch, or more than one

(1) inch in any dimension, and when delivered on the street shall be deposited on flooring and kept clean until used.

Mixing and Laying of Concrete.

The concrete shall be mixed on movable water-tight platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand and stone shall be mixed in the following proportions: One (1) part cement, two and one-half (2-1/2) parts sand and five (5) parts of stone or washed gravel. The sand and cement shall be thoroughly mixed dry, to which sufficient water shall be added, and then made into a stiff mortar. The stone or washed gravel, after having been sprinkled with water, shall then be immediately incorporated in the mortar and the mass thoroughly mixed by turning over with shovels, hoes, or mechanical mixers at least three (3) times, or until each particle of stone is thoroughly covered with mortar.

The concrete shall be removed from the platform and placed on the foundation in such quantities that after being rammed in place the layer shall be of the required thickness (four and one-fourth (4-1/4) inches) , and the upper surface shall be true, and three-fourths (3/4) of an inch below and parallel with the top of the finished walk. The second, or finishing layer, three-fourths (3/4) of an inch thick, composed of two (2) parts of best Portland cement, and three (3) parts clean, screened torpedo gravel, or fine granite screenings, to be put on before the first layer has set, and troweled sufficiently to give the completed

walk a smooth, even and glossy surface.

All work to be laid in blocks about five (5) feet by six (6) feet enclosed in wood forms made of two (2) inch by five (5) inch scantling, and blocks must be laid alternately, leaving the intervening space until all alternate blocks are laid and cement set.

During the progress of the work the sub-grade must be kept moist.

All sidewalks to be so constructed when completed the top surface shall coincide with the grade of the space between the curb line and the street line, which grade shall be in a uniform incline from the street line toward the curb line, with a fall of one (1) inch in every three (3) feet.

Design of Abutments.

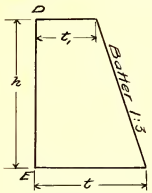


Figure 1.

Figure 1 is a cross section of the type of abutments and retaining walls to be used. It is first necessary to determine the center of gravity of the above section in terms of the height h, and the thickness of the base, t.

Let x equal the distance of the center of gravity from the back of the wall, DE.

Then taking moments about DE, we have,

$$\left(\frac{t+t_1}{2}\right)hx = \frac{ht_1^2}{2} + \frac{h}{2}(t-t_1)\left(t_1 + \frac{1}{3}(t-t_1)\right) \qquad (1)$$

But for a batter of 1:3, t_1 equals $t - \frac{h}{3}$. (2)

Substituting the value of t_1 as given in (2), in (1), and solving for x, we have,

$$x \text{ equals } \frac{27t^2 - 9ht + h^2}{54t - 9h} .$$

The following method of designing abutments and retaining walls is taken from Alexander and Tomson's "Elementary Applied Mechanics", pages 87 to 96 inclusive. One abutment is designed in detail for a given height and a table shows the dimensions of the other abutments designed in the same manner.

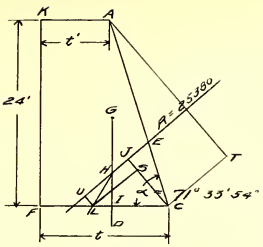


Figure 2.

ACFK in Figure 2 represents the wall in cross section; height, h, equals 24 feet; length, l, equals 1 foot; it supports a bank of sand whose upper surface is horizontal and whose natural slope is 33° 41'.

Let w equal the weight of masonry equals 150 pounds per cubic ft.

" w' " " " " sand " 100 " " " ".

" $\mathbb{D}$ " " angle of repose of the sand equals 33° 41'.

" t " " thickness of the wall at the base in feet.

" t' " " " " " " " top " ".

" p " " intensity of vertical pressure at depth of n feet in pounds per square foot, equals weight of a volume of earth one square foot in section, n feet high, equals w'n pounds per sq.ft.

Let q equal the least horizontal stress which will give equilibrium.

$$\frac{p}{q} \text{ equals } \frac{1 - \sin \mathbb{D}}{1 + \sin \mathbb{D}} \text{ equals } 0.286.$$

That is, the horizontal pressure at any point of AC, the back of the wall, is 0.286 times the vertical pressure due to that depth of sand. At C, the base of the wall, the vertical and horizontal pressures of earth are therefore

p equals 24×100 equals 2400 pounds per square foot.

q equals 0.286×2400 equals 690 pounds per square foot.

The ellipse of stress is drawn for a depth of twelve feet.

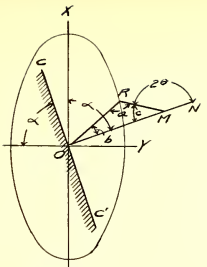


Figure 3.

OX and OY are the principal axes of stress; the semi-diameters represent p and q, now of half the values above; CC' represents a portion of the plane AC on which the intensity of pressur is desired. Draw ON at right angles to CC'; and along it, take OM equal to $\frac{p+q}{2}$ equals 1545; MR equals $\frac{p-q}{2}$ equals 855 is drawn so that angle RMN equals 2a equals 143° 7' 48". The point R is a point on the ellipse of stress and the line RO represents the intensity and direction of pressure on CC' at the average depth of 12 feet. It is then necessary to solve the triangle OMR. Using first the formula $\tan \frac{1}{2}(a - b) = \frac{A-B}{A+B} \tan \frac{1}{2}(a + b)$, solving for a and b, and then using the equation OR sin b equals RM sin a and solving for OR, we get OR equals 1003 pounds per square foot, a equals 112° 20' 44", b equals 30° 47' 4" and c equals 36° 52' 12".

The stress on AC is represented by the triangle ACT; it is zero at A and increases to CT equals 2 times 1003 equals 2006 lbs. per square foot at the base of the wall; AC equals 25.3 feet and the total pressure on AC is R equals 25,380.

To find the thickness of the wall required for stability of position, let G (Fig.2) be the center of gravity of the wall,

and from G downwards draw a vertical line; produce the line of action of R through E, and let H be the point of intersection; from H draw HV equals R equals 25,380 pounds, and HD equals W equals the weight of the wall (not yet determined); complete the parallelogram of forces and draw the diagonal HZ, producing it if necessary, to cut the base in L; draw LU at right angles to HV. The point L just found must lie within the middle third of the base, FC, in order that the bed-joints near C, the heel of the wall should not have a tendency to open or crush at F, the toe; that is the distance from the center of the base of the wall to the center of pressure should not exceed 0.17t. Taking moments about L, we have, $R \times \overline{LU}$ equals $W \times \overline{Ll}$ (3)

But LU equals CJ - CS equals CE cos b - .67t sin(b + (90° - a))

CE equals 8.4, W equals $24(\frac{t}{2} + \frac{t'}{2}) \times 150$ equals 3600(t - 4).

LI equals x - .33t.

Substituting the above values in equation (3) and solving for t, we have, t equals 14.6 feet.

Therefore make the thickness at the base equal to 15 feet. The thickness of the wall at the top will be $15 - 1/3 \times 24$ equals 7 feet.

For stability of friction the angle LHI should not exceed the angle of repose for the masonry. Calculating this angle we find angle LHI is less than the angle of repose of the masonry.

In the same manner as above the abutments have been figured for all streets and the sizes found are tabulated as follows:

Subway.	h.	t.	t'.
Avenue A	15.5	9.0	3.75
" B	14.0	7.5	3.00
First Street	14.0	7.5	3.00
Second Street	16.0	9.0	3.75
Avenue C	15.5	9.0	3.75
" D	17.0	9.5	4.00
Third Street	24.0	15.0	7.00
B. M. & C. RY.	24.0	15.0	7.00

Design of Piers.

The total reaction at the ends of girders which rest on columns for all streets except Avenue A is 382,000 pounds. The columns rest in concrete piers. Assuming that the safe crushing strength of concrete is 250 pounds per square inch, a bearing area of $\frac{382,000}{250}$ equals 1532 square inches will be required on top of the pier. This will require a top of about 48" × 48". Assuming the safe bearing power of the clay upon which the pier rests as 4,000 pounds per square foot, a bearing area of $\frac{382,000}{4,000}$ equals 96 square feet will be required at the bottom of the pier. This will require a footing of about 10' × 10'. By making the piers of four steps, each step 2 feet wider than the one above, and each step 1'-6" thick, the concrete will not crush as the stress is transmitted at a large angle. At Avenue A the total reaction at the ends of the girders which rest on the columns is 575,000 pounds. This will require the same size top as above, but a base 12' × 12'. By adding one more step to the above designed pier, the necessary bearing area will be supplied.

Plate No.1 shows the present position of the tracks in full lines, while the dotted lines show the temporary tracks necessary for the carrying on of the construction work and the final position of the tracks when elevated.

Plate No. 2 shows the proposed cross section of the roadbed for four tracks, showing the distance of the track centers from the dividing line between the H. & N. RY. and the L. R. & B. RY. This cross section will be the same between all streets as the track runs in a straight line from the approach west of Avenue A to the Calumet River.

Plate No. 3 shows the present profile of the center line of the roadbed in full lines, while the proposed elevation of the base of rail above city datum is shown in dotted lines. The amount of filling sand required between each street is noted on plate.

Plates Nos. 4 to 10 inclusive show the proposed cross sections of the street and railway intersections. Profiles of the present grade of the street are shown and also the profile of the proposed elevation of the subograde of the street.

Plate No.11 shows the proposed cross section of the intersection of the B. N. & C. RY.

Plate No. 12 shows a section parallel to the tracks of the H. & N. RY. in order to show the general plan of the steel superstructure.

Plates Nos. 13 to 16 inclusive show the cross sections of the roadbed at present and also the proposed top of the filling sand.

Unit Cost of Materials and Labor.

The authorities for computing the unit cost of the materials and labor on this work are several in number. Baker's "Roads, Streets, and Pavements", Gillette's "Cost Data", and Taylor and Thompson's "Concrete, Plain and Reinforced" were referred to considerably for information on the cost of various items. The remainder of the costs of the various items was furnished by the writers, who have had experience on work similar to this.

Cost of Sand. This includes the purchase, loading at the pit hauling from the pit to the work, and unloading in place.

The purchase price on comparatively large purchases is nine (9) cents per cubic yard.

The sand is to be loaded by a five (5) yard dipper steam shovel. The average amount of sand loaded by such a shovel is three thousand (3,000) cubic yards per day of ten hours.

Labor.

5 Pitmen	at $1.75	$ 8.75
Foreman		4.00
Craneman		3.00
Engineer on shovel		4.25
Fireman " "		2.50
Engineer " locomotive		4.00
Fireman " "		2.75
Conductor " "		3.50
2 Brakemen " "	at $3.00	6.00
Night Watchman		1.75

Supplies.

Repairs		10.00
Coal for shovel-1.3 tons	at $2.50	3.25
Coal for locomotive-4.0 tons	at $2.50	10.00
Oil and Waste		1.00
Depreciation on $15,000.00 plant (150 days work)		15.00
	Total	$79.75

The cost of loading the sand then equals $\frac{7975}{3000}$ equals two and sixty-five hundredths (2.65) cents per cubic yard.

The cost of hauling the sand from the sand pit to the place of unloading has been based on the consideration that two locomotives and seventy cars will be required to haul the sand in, the same locomotives to take the empty cars back to the pit. Each locomotive will make two trips a day. Since one gondola car holds thirty (30) cubic yards of sand, each locomotive will haul twenty-one hundred (2,100) cubic yards of sand per day.

Labor.

Engineer		$ 4.00
Fireman		3.00
Conductor		3.50
2 Brakemen	at $3.00	6.00

Supplies.

Coal-10 tons	at $2.50	25.00
Miscellaneous		2.00
Depreciation on $115,000.00 plant per day		9.50
	Total	$53.00

The cost of hauling the sand from the sand pit to the place of unloading then equals $\frac{5300}{2100}$ equals two and fifty-two hundredths (2.52) cents per cubic yard.

From data obtained by the writers while engaged on similar work one man will unload thirty (30) cubic yards per day of ten (10) hours. Allowing him wages of one dollar and seventy-five cents ($1.75) per day, the cost of unloading the sand equals five and eighty-hundredths (5.83) cents per cubic yard.

Besides the above costs there is the cost of engine service for "spotting" the cars for unloading and also that of the jacking

up of the track and maintaining same. The first cost is three (3) cents and the last is twelve (12) cents per cubic yard.

Total Cost.	Cts. per cu.yd.
Purchase	9.00
Loading	2.65
Hauling	2.52
Unloading	5.83
Engine Service for "Spotting".	3.00
Jacking up Track and Maintaining Same	12.00
Total	35.00

The total cost of sand in place is then thirty-five (35) cents per cubic yard.

Cost of Steel Superstructure. The present price for steel superstructure in place is three and one-half (3.5) cents per pound or seventy dollars ($70.00) per net ton (2000 pounds).

Cost of Flooring for Bridges. The cost of concrete flooring for bridges is four dollars ($4.00) per lineal foot of track as given in the report of the Western Society of Engineers, Vol. 10-1905-page 266.

Cost of Ties. The cost of good oak ties in place is about seventy-five (75) cents a piece on the average.

Cost of Steel Rails. The cost of steel rails f.o.b. delivered on the work is thirty-one dollars ($31.00) per ton (2240 pounds).

Cost of Ballast. The cost of ballast in place in this particular case is eighty (80) cents per cubic yard.

Cost of Track Fastenings and Joints. The cost of spikes 5-1/2" by 9/16" is two dollars and sixty cents ($2.60) per hundred pounds. The cost of angle bars is one dollar and sixty-five

cents ($1.65) per hundred pounds. The cost of bolts is two dollars and seventy cents ($2.70) per hundred pounds.

The above prices are the present market prices as quoted in various papers and periodicals. They are for the materials delivered on the work, but not in place with the exception of the ballast. The cost of placing the ties, rails, and track fastenings will be included in another item.

Two section gangs of twelve (12) men each will take care of the above work as fast as is required and also take care of other odd jobs. Allowing the two foremen two dollars and fifty cents ($2.50) per day each and each man one dollar and sixty-five cents ($1.65) per day, the cost per day of the two gangs will be forty-four dollars and sixty cents ($44.60) per day.

Cost of Concrete for Piers, Abutments, Retaining Walls, and Foundations. From data obtained by the writers while engaged on similar work a paddle mixer with thirty-three (33) laborers, one (1) foreman, and one (1) engineer will place one hundred and ten (110) cubic yards of concrete in ten (10) hours.

For a 1:3:6 mixture of concrete the amount of materials required per cubic yard of concrete is 0.9 bbl. of cement, 0.44 cu. yd. of screenings, and 0.88 cu. yd. of stone.

Labor.

33 laborers	at $1.75	$57.75
1 Foreman		3.50
1 Engineer		6.60
Depreciation in plant		2.00
	Total	$69.85

6985 ÷ 110 equals $0.635 per cubic yard.

Materials.		Per cu. yd. Concrete.
0.9 bbls. of cement	at $1.65 (delivered	$1.485
0.44 cu.yd. screenings	at $0.80 (delivered)	.352
0.88 " " stone	at $0.80 (delivered)	.704
		$2.541
Cost of Forms (Building and Material)		.600
Labor (as given above)		.635
	Total	$3.776

The cost of concrete in place, then, is $3.776 per cubic yard.

Cost of Street Excavation and Grading. The street grading and excavation will be done by means of teams and scrapers. On the average it will be necessary to haul the dirt about one hundred (100) feet. Assuming that each scraper holds one fourth (1/4) of a yard and that each scraper will make a trip every three (3) minutes, each team will haul fifty (50) cubic yards per day. If they worked in a gang of six (6), the total yardage excavated will be three hundred (300) cubic yards of earth per day.

Cost per day is as follows:

6 Teams	at $5.00	$30.00
1 man (Loading)	" $3.00	3.00
1 man (Dumping)	" $2.00	2.00
12 men (Loosening)	" $2.00	24.00
Depreciation of plant per day		1.50
	Total	$60.50

The cost, then, equals 6050 ÷ 300 equals twenty and two-tenths (20.2) cents per cubic yard.

Cost of Pier Excavation. From data obtained by the writers while engaged on similar work, the actual cost of excavating one hundred and twenty (120) cubic yards of earth for pier found-

ations, pulling sheeting, and refilling is as follows:

28 laborers		at $2.00 per day		$56.00
1 Foreman		" $3.50 " "		3.50
Pulling sheeting	50 hours	" $0.20 " hour		10.00
Refilling	50 "	" $0.20 " "		10.00
			Total	$79.50

The cost of excavating is, then, 7950 ÷ 120 equals sixty-six and three-tenths (66.3) cents per cubic yard.

Cost of Abutment Foundation Excavation. For abutment foundation excavation the cost is less than the cost of pier excavation by an amount equal to the last item given above or equal to fifty-seven and nine-tenths (57.9) cents per cubic yard.

All earth that is excavated at each street for the piers, abutment foundations, and street grading will be placed on the right of way of the H. & N. RY. behind the proposed site for the abutments.

Cost of Combined Curb and Gutter.

Labor	Cost per 100 feet.
Opening trench- 2 men at $1.75 per day will open 144 feet	$ 2.43
Placing and tamping cinders-2 men at $1.75 per day will take care of 350 feet	1.00
Setting Forms	1.69
Mixing and Placing Concrete	7.64
Materials.	
Portland Cement 8-1/3 bbls. at $1.65	13.75
Cinders 7-1/2 cu.yds. at $0.50	3.75
Broken Stone (Granite) 2-1/2 cu.yds. at $3.50	8.75
Granite Screenings 1.0 " " " $2.50	2.50
Total	$41.51

Cost, then, equals 41.5 cents per lineal foot.

Cost of Cement Walk. In figuring this cost it is not necessary to take into account excavation as that will be allowed for in the street grading.

Labor	Cost per square ft.
Placing Cinders	$0.005
Setting Forms	0.002
Mixing and Placing Base	0.006
" " " Wearing Face	0.002
Finishing	0.005
Hauling Materials	0.002
Materials	
1 Bbl. Cement for 35 square feet, at $1.65	0.048
1 Yd. Gravel " 40 " " at $0.80	0.020
1 Yd. Sand " 125 " " at $1.00	0.008
1 Yd. Cinders " 24 " " at $0.50	0.021
Depreciation, Lumber, etc.	0.010
Total	$0.139

The total cost of Portland cement sidewalk, then, is 12.9 cents per square foot.

Cost of Brick Paving.

Labor.			Cost per sq. yd.
Hauling stone and making concrete			$0.155
Paving and Pitching			0.150
Materials.			
1-4 bbl. Portland cement	at $1.65		0.413
1-10 cu. yd. sand	at $0.45		0.045
0.17 cu. yd. stone	at $0.80		0.136
Sand Cushion			0.070
" used in pitching			0.010
1-25 bbl. of pitch	at $5.25		0.210
41 paving brick at $18.00 per thousand			0.738
		Total	$1.927

The cost per square foot is, then, $1.927.

Cost of Brick Manholes.

Labor.			
Sewer Builder	10 hours at $1.00		$10.00
Helper	16 hours at $0.25		4.00
Materials.			
1,000 Brick	at $6.00		6.00
470 lb. ring and cover	at $0.02		9.40
2-2/3 bbls.cement	at $0.75		2.00
1 cu. yd. sand	at $3.00		3.00
		Total	$34.40

Cost of each man-hole is, then, $34.40

Cost of Catch-Basins(Including 20 feet of 9" connection).

Labor.			
Sewer Builder	12 hours at $1.00		$12.00
Helper	18 hours at $0.25		4.50
Materials.			
1,000 Brick	at $6.00		6.00
470 lb. ring and cover	at $0.02		9.40
2-2/3 bbls. cement	at $0.75		2.00
1 cu. yd. sand	at$3.00		3.00
20 feet -9" sewer pipe	at $0.60		12.00
2 Vitrified Elbows	at $2.40		4.80
		Total	$53.70

The cost of each catch-basin, is then, $53.70

Amount of Materials Required.

In calculating the amount of materials required at each subway, the street excavation is considered to be done for the full distance between the abutments and of a length shown by the profiles for each street on Plates Nos. 4 to 10 inclusive. The pier excavation is then calculated from the sub-grade of the street down to the bottom of the pier as also shown on Plates Nos. 4 to 10 inclusive. The length of the curbing and cement sidewalk is taken as far as the street is paved, which is the length shown on the profiles of each street. Two catch-basins and one manhole are required at each street. The abutments have a length of one hundred and forty-one and four-tenths (141.4) feet at all streets except Avenue C where the length is one hundred (100) feet. Each pier at all streets except Avenue A contain twelve and nine-tenths (12.9) cubic yards of concrete. The piers at Avenue A contain twenty and nine-tenths (20.9) cubic yards each. The weight of the steel superstructure has been obtained from data on similar bridges on other roads in Chicago.

The right of way was cross-sectioned and the cross sections are plotted on Plates Nos. 13 to 16 inclusive. A table on the following sheets 48 and 49 shows the amount of filling sand required. The amount of stone ballast required is thirteen thousand five hundred (13,500) cubic yards per mile of four tracks as calculated from the cross section on Plate No. 2. There are sixteen (16) ties under each thirty-three (33) feet of track, requiring two thousand, five hundred and sixty (2,560) ties per

mile of single track. Steel rails to be used on this work will weigh one hundred (100) pounds per yard. This will require one hundred and fifty-seven and one-tenth (157.1) tons (2240 pounds) per mile of single track. The spikes to be used on this work are to be five and one-half (5-1/2) inches by nine-sixteenths (9/16) of an inch and ten thousand, two hundred and forty (10,240) are required per mile of single track. Angle bars shall weigh thirty-five (35) pounds each. Six hundred and forty (640) are required for each mile of single track or twenty-two thousand, four hundred (22,400) pounds of angle bars per mile of single track. One thousand, nine hundred and twenty (1,920) bolts are required per mile of single track.

The following table is the data derived from Plates 13 to 16 inclusive, giving the cubic yards of filling sand between each street intersection and railway intersections. The areas of the cross sections were obtained by means of a planimeter.

Station.	Area, Sq. Ft.	Average End Area.	Distance, Feet.	Volume, Cubic Feet.	Volume, Cubic Yards.
00 + 0.0	0	------	------	--------	-------
3 + 0.0	68	34.0	300.0	10200	377.8
6 + 0.0	195	131.5	300.0	39450	1461.1
9 + 0.0	348	271.5	300.0	81450	3016.7
12 + 0.0	510	429.0	300.0	128700	4766.7
16 +60.0	692	601.0	460.0	276460	10239.3
Street Intersection-- Avenue A.				Total	19861.6
18 + 0.0	739	---- --	------	-------	-------
21 + 0.0	720	729.5	300.0	218850	8105.6
24 + 0.0	739	729.5	300.0	218850	8105.6
27 + 0.0	730	759.5	300.0	227850	8438.9
30 + 0.0	824	802.0	300.0	240600	8911.1
33 + 0.0	838	831.0	300.0	249300	9233.3
36 + 0.0	786	812.0	300.0	243600	9022.2
39 + 0.0	776	781.0	300.0	234300	8677.8
42 + 0.0	849	812.5	300.0	243750	9027.8
45 + 0.0	877	863.0	300.0	258900	9588.9
48 + 0.0	862	869.5	300.0	260850	9661.1
51 + 0.0	798	830.0	300.0	249000	9222.2
53 +46.0	797	797.5	246.0	196185	7266.1
Street Intersection-- Avenue B.				Total	105800.8
54 +30.0	788	------	------	------	-------
57 + 0.0	765	776.5	270.0	209655	7765.0
57 +59.0	712	738.5	59.0	43572	1613.8
60 + 0.0	858	785.0	241.0	189185	7006.9
63 + 0.0	908	883.0	300.0	264900	9811.1
66 + 0.0	876	892.0	300.0	267600	9911.1
69 + 0.0	851	863.5	300.0	259050	9594.4
72 + 0.0	919	885.0	300.0	265500	9833.3
75 + 0.0	916	917.5	300.0	275250	10194.4
78 + 0.0	922	919.0	300.0	275700	10211.1
81 + 0.0	924	923.0	300.0	276900	10255.6
85 +25.0	797	860.5	425.0	365713	13544.9
Street Intersection--First Street.				Total	99741.6

Station.	Area, Sq. Ft.	Average End Area.	Distance, Feet.	Volume, Cubic Feet.	Volume, Cubic Yards.
86+ 9.0	801	--------	--------	-------	--------
87+ 0.0	917	859.0	91.0	78169	2895.2
90+ 0.0	948	932.5	300.0	279750	10361.1
93+ 0.0	959	953.5	300.0	286050	10594.4
96+ 0.0	953	956.0	300.0	286800	10622.2
99+ 0.0	961	957.0	300.0	287100	10633.3
102+ 0.0	932	946.5	300.0	283950	10516.7
105+ 0.0	945	938.5	300.0	281550	10427.8
108+ 0.0	967	956.0	300.0	286800	10622.2
111+ 0.0	949	958.0	300.0	287400	10644.4
114+ 0.0	944	946.5	300.0	283950	10516.7
117+ 0.0	982	963.0	300.0	288900	10700.0
120+ 0.0	948	965.0	300.0	289500	10722.2
123+ 0.0	1010	979.0	300.0	293700	10877.8
126+ 0.0	1047	1028.5	300.0	308550	11427.8
129+ 0.0	1127	1087.0	300.0	326100	12077.8
132+10.3	1202	1164.5	310.3	361344	13383.1
Street Intersection-- Second Street.				Total	167022.7
132+94.3	1232	------	------	------	-------
135+ 0.0	1255	1243.5	205.7	255738	9473.6
138+66.8	1328	1291.5	366.8	473722	17545.3
Street Intersection-- Avenue C.				Total	27018.9
139+26.8	1410	------	------	------	-------
141+ 0.0	1374	1392.0	173.2	241094	8929.4
144+ 0.0	1664	1519.0	300.0	455700	16877.8
146+94.4	1753	1708.5	394.4	673938	13666.9
Street Intersection-- Avenue D.				Total	44430.1
147+78.4	1498	------	------	------	-------
150+ 0.0	1613	1555.5	221.6	344699	12766.6
153+ 0.0	1722	1667.5	300.0	500250	18527.8
156+45.9	1943	1832.5	345.9	633862	23476.4
Railway Intersection-- B. N. & C. RY.				Total	54770.3
157+19.9	1949	------	------	-------	-------
160+42.4	1744	1846.5	322.5	595496	22055.4
Street Intersection-- Third Street.				Total	22055.4
161+26.4	1727	------	------	-------	-------
165+ 0.0	1551	1639.0	373.6	612330	22678.9
168+ 0.0	1461	1506.0	300.0	451800	16733.3
171+ 0.0	1299	1380.0	300.0	414000	15333.3
174+ 0.0	1178	1238.5	300.0	371550	13761.1
176+29.5	1223	1200.5	229.5	275515	10204.3
Calumet River.				Total	73710.9

Grand Total Pages 46 and 47. 618878.6 Cu. Yds.

Cost of Constructing Subways.

Avenue A.

3193.5	c.y.	Street Excavation	at $ 0.202	$ 645.09
481.5	"	Pier "	" 0.663	319.23
1414.0	"	Abut. Found. "	" 0.579	818.71
1207.0	s.y.	Brick Paving	" 1.927	2325.89
9533.5	s.ft.	Cement Sidewalk	" 0.129	1229.83
447.8	l.ft.	Curbing	" 0.415	185.84
2.0	Catch-Basins		" 53.70	107.40
1.0	Manhole		" 34.40	34.40
1876.3	c.y.	Concrete	" 3.776	7084.91
930000.0	lbs.	Steel Superstruct.	" 0.035	32550.00
580.0	l. ft.	Flooring	" 4.00	2320.00
			Total	$47621.29

Avenue B.

1279.3	c.y.	Street Excavation	at $ 0.202	$ 258.42
333.2	"	Pier "	at 0.663	220.91
990.8	"	Abut. Found. "	" 0.579	573.67
1022.2	s.y.	Brick Paving	" 1.927	1969.78
4477.5	s.ft.	Cement Sidewalk	" 0.129	577.60
425.0	l.ft.	Curbing	" 0.415	176.38
2.0	Catch-Basins		" 53.70	107.40
1.0	Manhole		" 34.40	34.40
1448.7	c.y.	Concrete	" 3.776	5470.29
470000.0	lbs.	Steel Superstruct.	" 0.035	16450.00
352.0	l.ft.	Flooring	" 4.00	1408.00
			Total	$27246.85

First Street.

1079.7	c.y.	Street Excavation	at $ 0.202	$ 218.10
333.2	"	Pier "	" 0.663	220.91
944.8	"	Abut. Found. Excav.	" 0.579	547.04
971.1	s.y.	Brick Paving	" 1.927	1871.31
4247.5	s. ft.	Cement Sidewalk	" 0.129	547.93
402.0	l.ft.	Curbing	" 0.415	166.83
2.0	Catch-Basins		" 53.70	107.40
1.0	Manhole		" 34.40	34.40
1448.7	c.y.	Concrete	" 3.776	5470.29
470000.0	lbs.	Steel Superstruct.	" 0.035	16450.00
352.0	lft.	Flooring	" 4.00	1408.00
			Total	$27043.31

Second Street.

346.0	c.y.	Street Excavation	at $	0.202	$ 69.89
333.2	"	Pier "	"	0.663	220.91
848.4	"	Abut. Found. "	"	0.579	491.22
755.6	s.y.	Brick Paving	"	1.927	1456.04
3277.5	s.ft.	Cement Sidewalk	"	0.129	422.80
305.0	l.ft.	Curbing	"	0.415	126.58
2.0		Catch-Basins	"	53.70	107.40
1.0		Manhole	"	34.40	34.40
1827.9	c.y.	Concrete	"	3.776	6902.15
470000.0	lbs.	Steel Superstructure	"	0.035	16450.00
352.0	l.ft.	Flooring	"	4.00	1408.00
				Total	$27689.39

Avenue C.

765.5	c.y.	Street Excavation	at $	0.202	$ 154.63
245.4	"	Pier "	"	0.663	162.70
743.5	"	Abut. Found. "	"	0.579	430.49
765.8	s.y.	Brick Paving	"	1.927	1475.70
3348.0	s.ft.	Cement Sidewalk	"	0.129	431.89
316.6	l.ft.	Curbing	"	0.415	131.39
2.0		Catch-Basins	"	53.70	107.40
1.0		Manhole	"	34.40	34.40
1331.9	c.y.	Concrete	"	3.776	5029.25
195000.0	lbs.	Steel Superstructure	"	0.035	6825.00
256.0	l.ft.	Flooring	"	4.00	1024.00
				Total	$15806.85

Avenue D.

625.6	c.y.	Street Excavation	at $	0.202	$ 126.37
347.0	"	Pier "	"	0.663	230.06
980.4	"	Abut. Found. "	"	0.579	567.65
844.4	s.y.	Brick Paving	"	1.927	1627.16
3702.0	s.ft.	Cement Sidewalk	"	0.129	477.56
352.0	l.ft.	Curbing	"	0.415	146.08
2.0		Catch-Basins	"	53.70	107.40
1.0		Manhole	"	34.40	34.40
2041.8	c.y.	Concrete	"	3.776	7709.84
300000.0	lbs.	Steel Superstructure	"	0.035	10500.00
352.0	l.ft.	Flooring	"	4.00	1408.00
				Total	$22934.52

B. N. & C. RY.

1356.4	c.y.	Abut. Found. Excavat.	at $	0.579	$ 785.36
3684.8	"	Concrete	"	3.776	13913.80
520000.0	lbs.	Steel Superstucture	"	0.035	18200.00
312.0	l.ft.	Flooring	"	4.00	1248.00
				Total	$34147.16

Third Street.

3684.6	c.y.	Street Excavation	at $	0.202	$ 744.29
347.0	"	Pier "	"	0.663	230.06
2356.2	"	Abut. Found. "	"	0.579	1364.24
1507.6	s.y.	Brick Paving	"	1.927	2905.15
6686.0	s.ft.	Cement Sidewalk	"	0.129	862.49
650.4	l.ft.	Curbing	"	0.415	269.92
2.0	Catch-Basins		"	53.70	107.40
1.0	Manhole		"	34.40	34.40
3866.0	c.y.	Concrete	"	3.776	14598.02
300000.0	lbs.	Steel Superstructure	"	0.035	10500.00
352.0	l.ft.	Flooring	"	4.00	1408.00
				Total	$33023.97

TOTAL COST.

Subways.			
Avenue A			$ 47621.29
Avenue B			27246.85
First Street			27042.21
Second Street			27688.39
Avenue C			15806.85
Avenue D			22934.52
P. H. & C. RY.			34147.16
Third Street			33023.97
Between Street Intersections.			
618,878.6 c.y.	Filling Sand	at $ 0.35	216607.51
45,100.0 c.y.	Stone Ballast	" 0.80	36080.00
34,200.0	Ties	" 0.75	25650.00
2,099.0 Tons	Steel Rails	" 31.00	65069.00
400.0 Kegs	of Spikes (200# each)	" 5.20	2080.00
299,250.0 lbs.	Angle Bars	" 1.65 per 100	4937.63
220.0 Kegs	of Bolts (200# each)	" 5.40	1188.00
Station at Avenue D (Estimated)			
(Including 150 feet of Retaining Wall)			30000.00
Section Gangs for 180 days at $44.60 per day			8028.00
		Total	$625152.38
Engineering 4%			25006.10
		Grand Total	$650158.48

Method of Carrying on Construction Work.

Since traffic must be kept open at any cost, it will be necessary to lay temporary tracks.

It will first be necessary to lay a temporary track, the center of which will be about ten feet from the east property line in order to unload sand from the gondola cars. When a train-load of sand has been emptied and the empties have been removed from this track, the sand can be filled in and tamped under the ties and the track gradually pushed up in this way. This is done by lifting the track with "jacks", and allowing the ties and the track to rest on the "jacks" while the sand is filled in under the ties. When enough sand has been put under the ties to support the track at nearly the height to which it has been lifted by the "jacks", they are removed, and the track is let down on the sand. As soon as the track is let down on top of the sand another train of sand may be run in and the same process, as outlined above, repeated until the track reaches the desired height. After one track is elevated sufficiently, sand can be unloaded from this track to place the remaining tracks at the required elevation. Where this interferes with traffic on the other tracks, cribbing built up of old ties, will be used to hold the sand back. Tracks 1,2,3, and 4 are elevated in that order. During the unloading of the sand, foundations for abutments and retaining walls, and piers may be placed as explained below.

It will first be necessary to excavate for piers and abut-

ments at Avenue A. The excavation at the other streets will be started in the order in which they come from Avenue A southeast. This excavation will be only that required in order to place piers and sufficient length of abutments for Tracks 1 and 2. In this way it will not be necessary to disturb the present east and west bound main tracks. The sand trains will cross over and go up on a grade from the present west bound main track on to the construction track where sand is to be unloaded. This will require a temporary turn-out at each street. After excavation has been completed the concrete may be placed for the piers, abutment foundations, and abutments. The street excavation may be carried on at the same time until almost down to sub-grade. All excavation is to be placed behind the proposed site of the abutments.

One week after removing the forms from the concrete piers and abutments the steel superstructure for Tracks 1 and 2 at the street and railway intersections may be placed on the abutments and piers.

This work is continued until all piers and abutments are finished and all steel superstructures at street and railway intersections are finished for Tracks 1 and 2. During this time, as stated above, filling sand will be filled in between abutments to the required elevation and Tracks 1 and 2 laid and placed at the proper distance from the property lines. After the piers and abutments have set for three weeks, traffic may be transferred from the present east and west bound main tracks to the elevated Tracks 1 and 2.

After traffic has been transferred to Tracks 1 and 2, Tracks 3 and 4 may be elevated in the same manner as Tracks 1 and 2.

When it is necessary to place cribbing to hold the sand back the section gangs employed on this construction work will place it.

After the four tracks have been elevated and the steel superstructures put in place, the subways may be completed by constructing the curbing, cement sidewalk, catch-basins, and manholes and then paving the street after the street has been graded down to the required elevation of sub-grade.

The stone ballast may then be placed under the track and the track placed in the proper condition.

PLATE 2.
SUBMITTED WITH THESIS
OF
L. B. Young

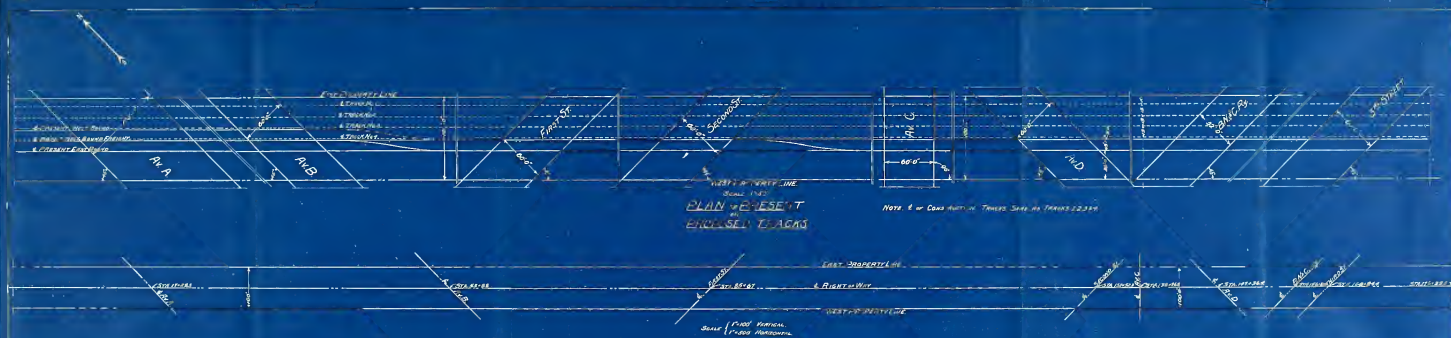
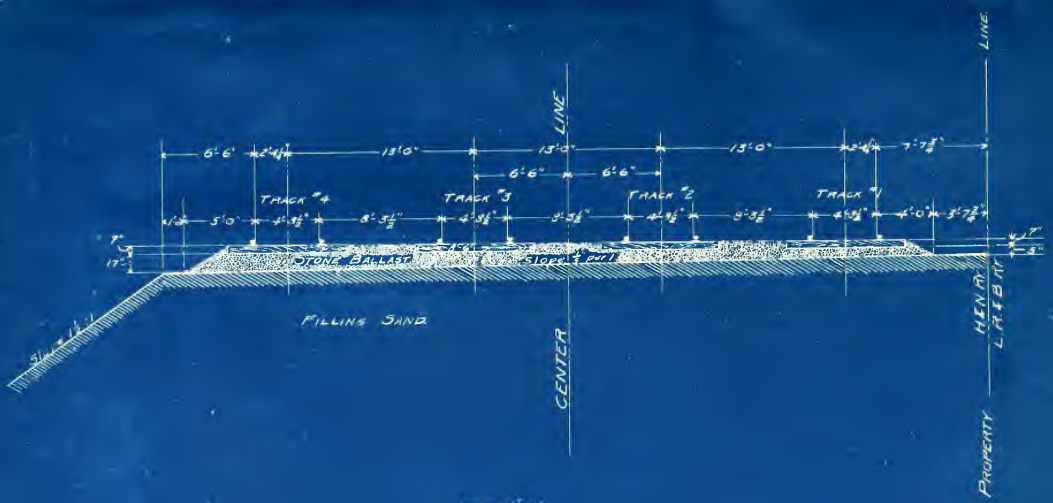


Plate 1
Submitted with Report
Dated [illegible]



SCALE ½" = 1'

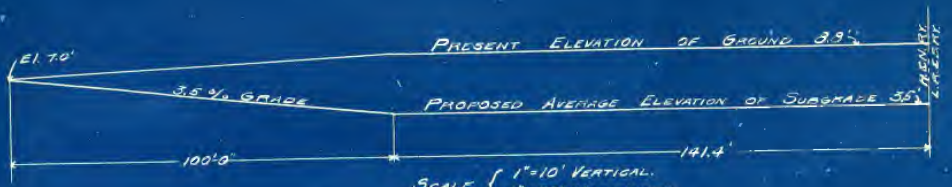
PROPOSED CROSS SECTION OF ROADBED

PLATE 2.
SUBMITTED WITH THESIS
OF
L. D. Young

OF AVENUE A.

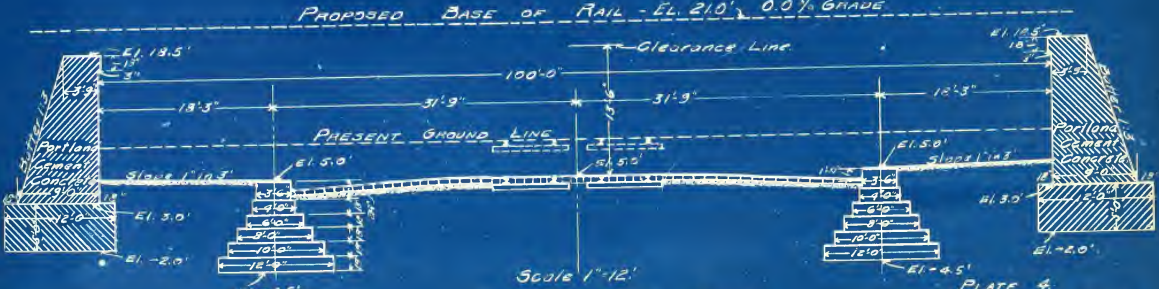
G.M. Neinsen. OF F. B. Yous

Front Street
Alley C
Alley B
Alley A
Proposed Base of Rail - El. 20.0
Present Base of Rail
City Datum El. 0.0
Scale 1"=10' Vertical
1"=40' Horizontal
Profile of Center Line Railroad



Scale { 1"=10' Vertical. 1"=30' Horizontal.

Profile of Avenue A.



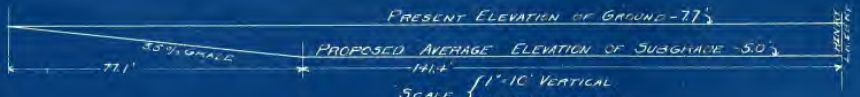
Proposed Cross Section of Avenue A.

Plate 4.

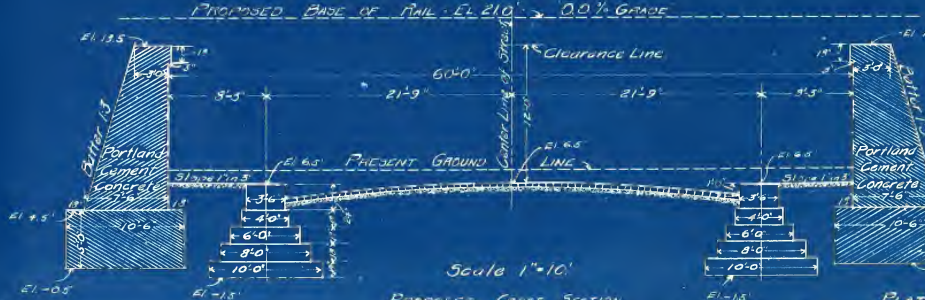
Submitted with Thesis

of

Graduate



PROFILE OF FIRST STREET



Scale 1"=10'

PROPOSED CROSS SECTION OF FIRST STREET

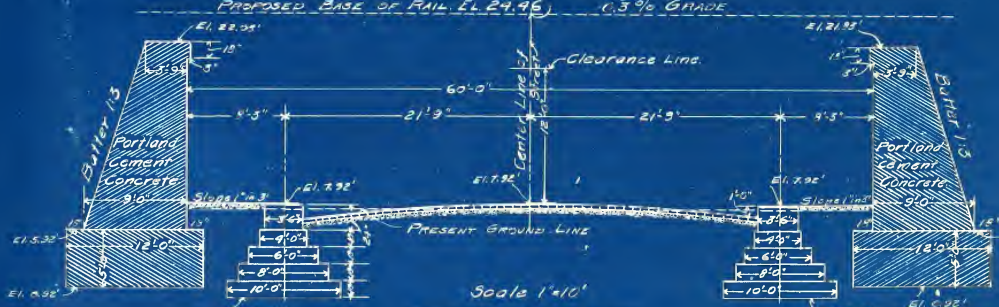
PLATE 6

SUBMITTED WITH THESIS OF

G. M. Nelson L. C. Young

Scale { 1"=10' Vertical. 1"=30' Horizontal.

Profile of Second Street



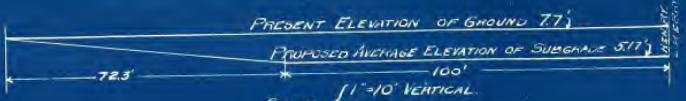
Scale 1"=10'

Proposed Cross Section of Second Street.

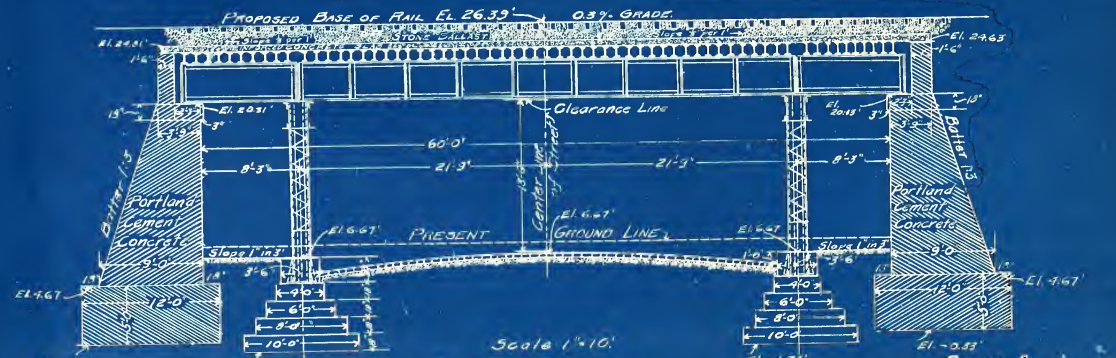
Plate 7.

Submitted with Thesis of

C. M. Nieuwl L. B. Young



Profile of Avenue C.



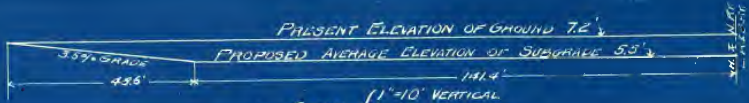
Scale 1"=10'.

Proposed Cross Section of Avenue C.

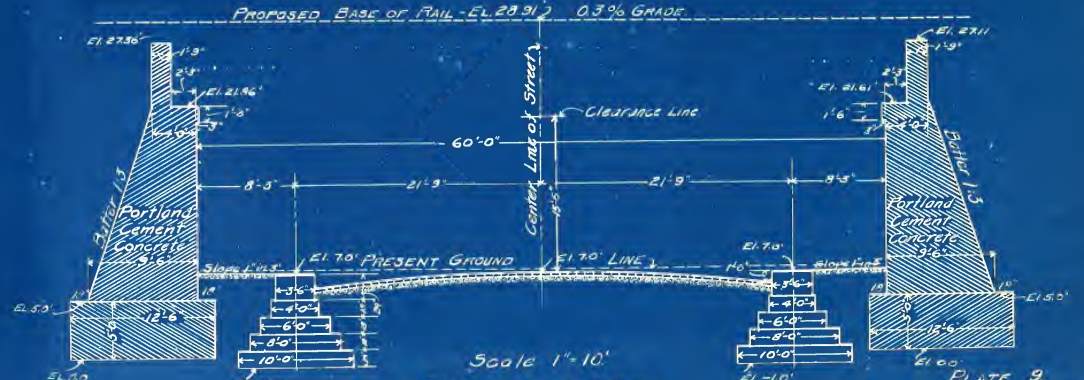
Plate 8

Submitted with Thesis of

L. M. Hammond & L. B. Young



PROFILE OF AVENUE D.



PROPOSED CROSS SECTION OF AVENUE D.

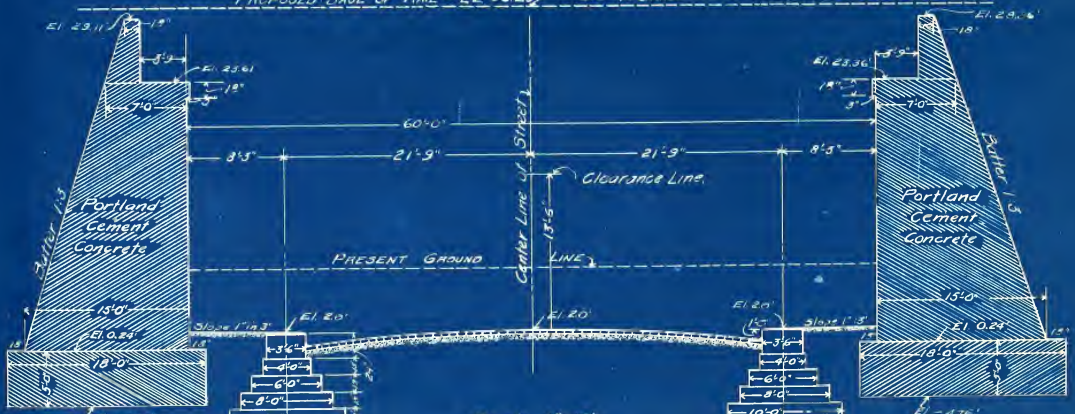
PLATE 9.

SUBMITTED WITH THESIS OF

Emmett L. Brown

SCALE { 1"=10' VERTICAL
1"=40' HORIZONTAL

PROFILE OF THIRD STREET



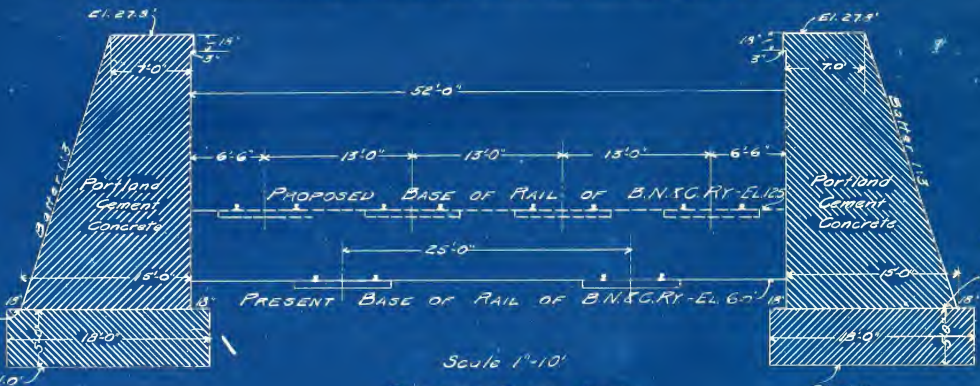
Scale 1"=10'

PROPOSED CROSS SECTION OF THIRD STREET

PLATE 10.

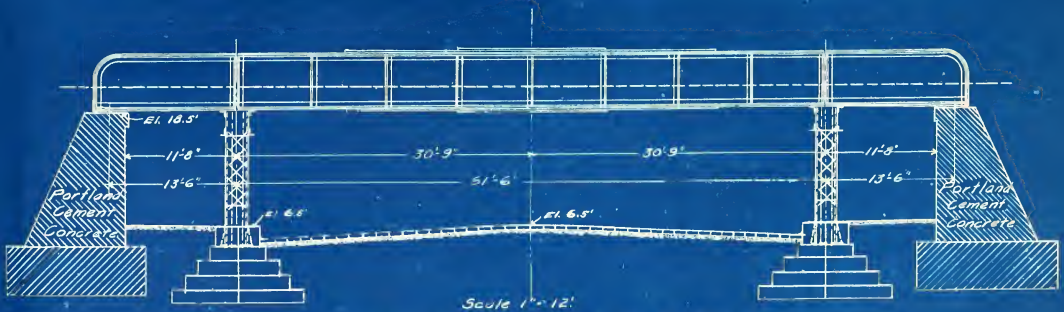
SUBMITTED WITH THESIS OF

G.M. Norwood & F.T. Young



PROPOSED CROSS SECTION
OF B.N.&C.RY.

PLATE II.
SUBMITTED WITH THESIS
OF
E. M. Peterson F. B. Young

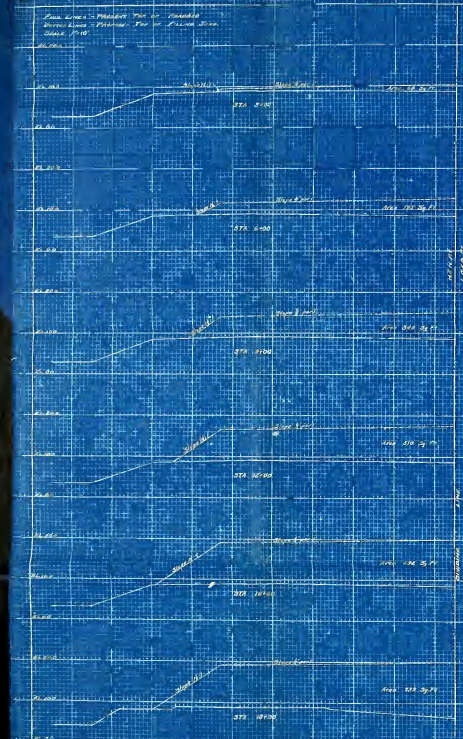


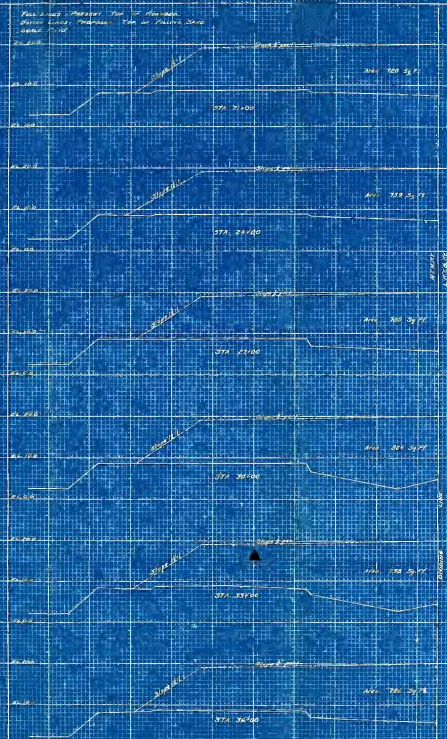
Scale 1"=12'

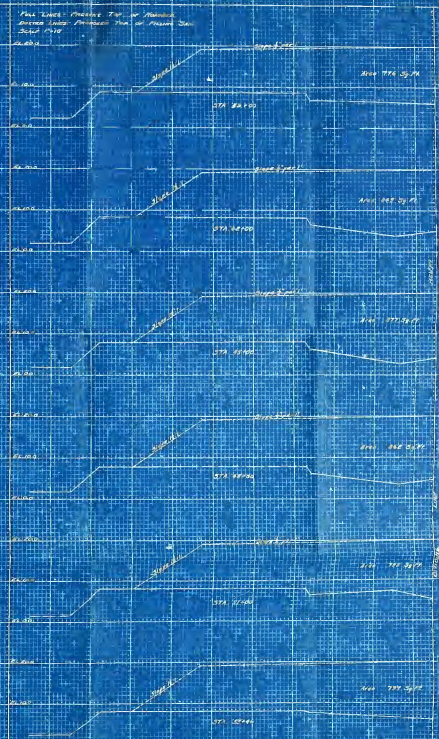
PROPOSED SECTION, PARALLEL TO H.&N.Y. TRACKS OF AVENUE B

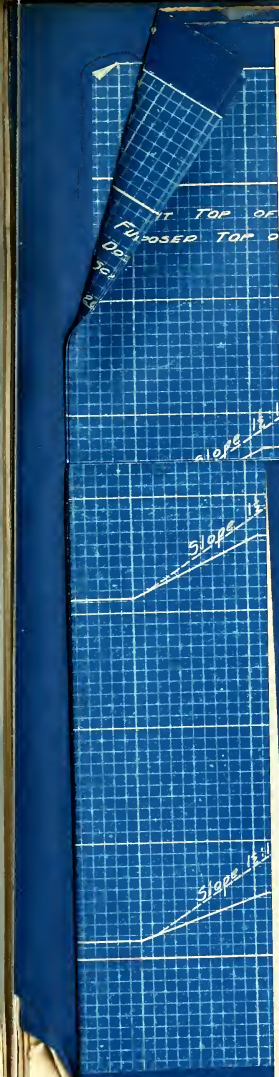
PLATE 12.
SUBMITTED WITH THESIS
OF
Emil Nimmo & F. F. Young

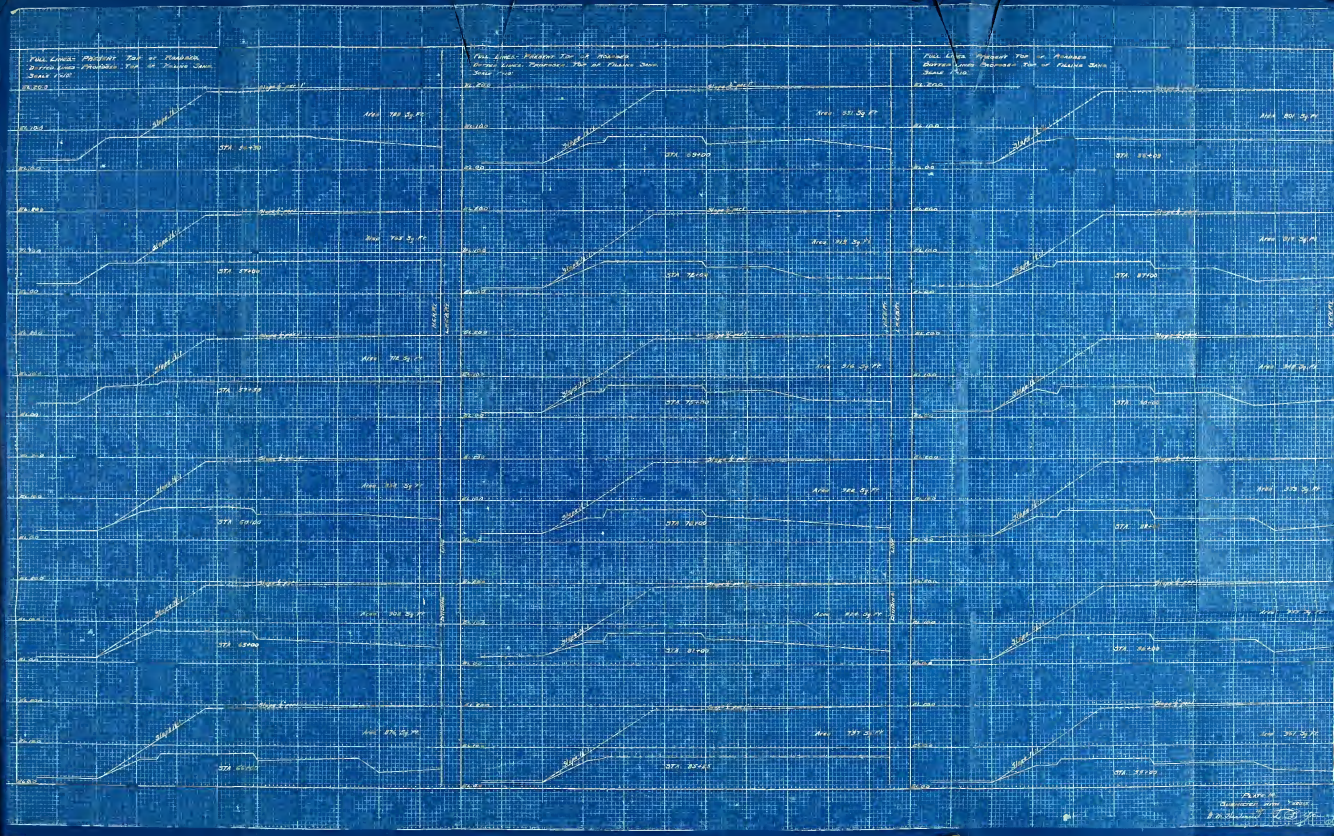
ENT TOP OF ROADBED
POSED TOP OF FILLING S
Slope 1:1
Slope 1:1
Slope 1:1

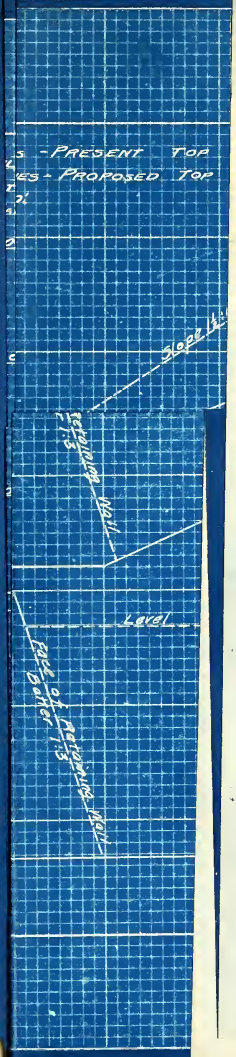

Full Lines: Profiles for 12" Manhole
Dotted Lines: Profiles for 8" Pipe Sewer
Scale 1"=10'
STA. 5+00
STA. 6+00
STA. 11+00
STA. 16+00
STA. 18+00

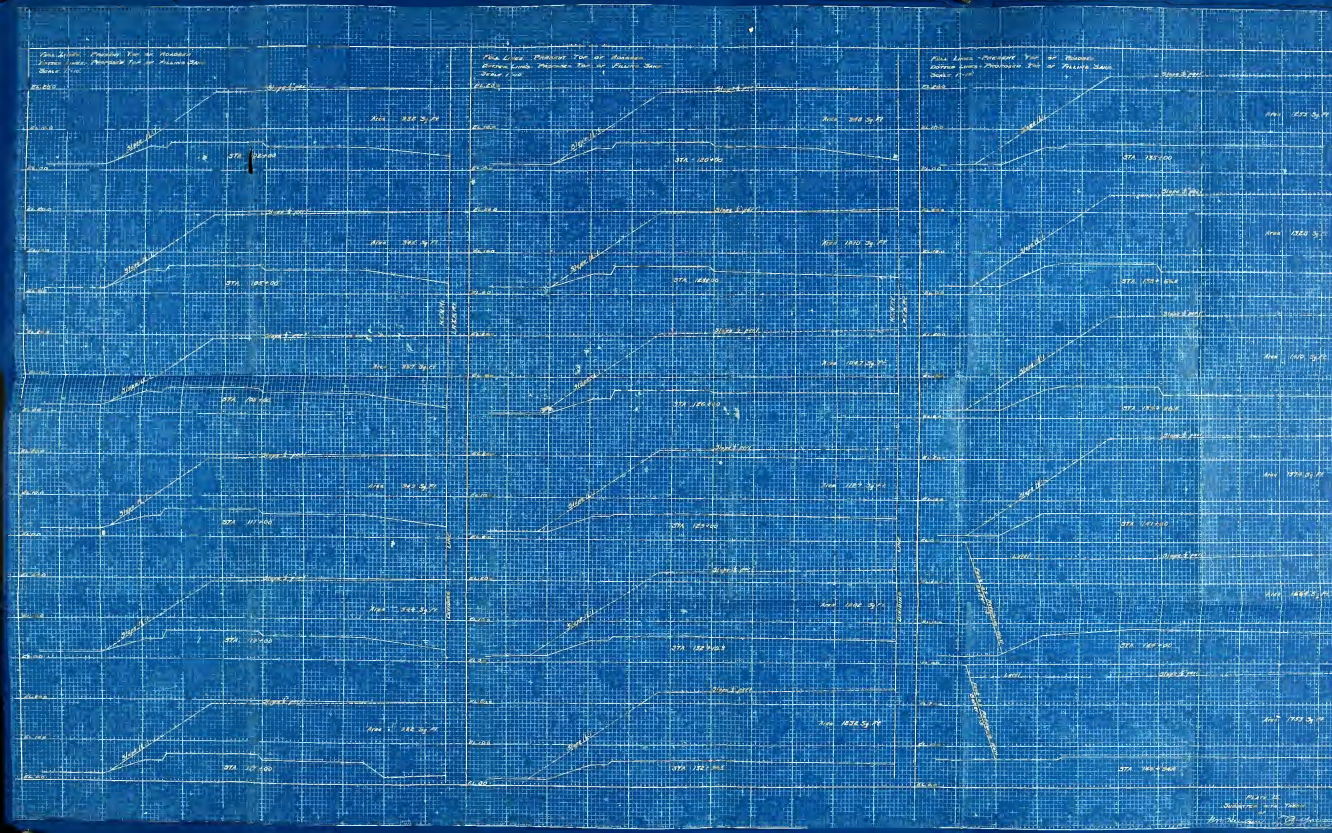

Full Lines: Profiles for 12" Manhole
Dotted Lines: Profiles for 8" Pipe Sewer
Scale 1"=10'
STA. 21+00
STA. 24+00
STA. 27+00
STA. 30+00
STA. 33+00
STA. 36+00

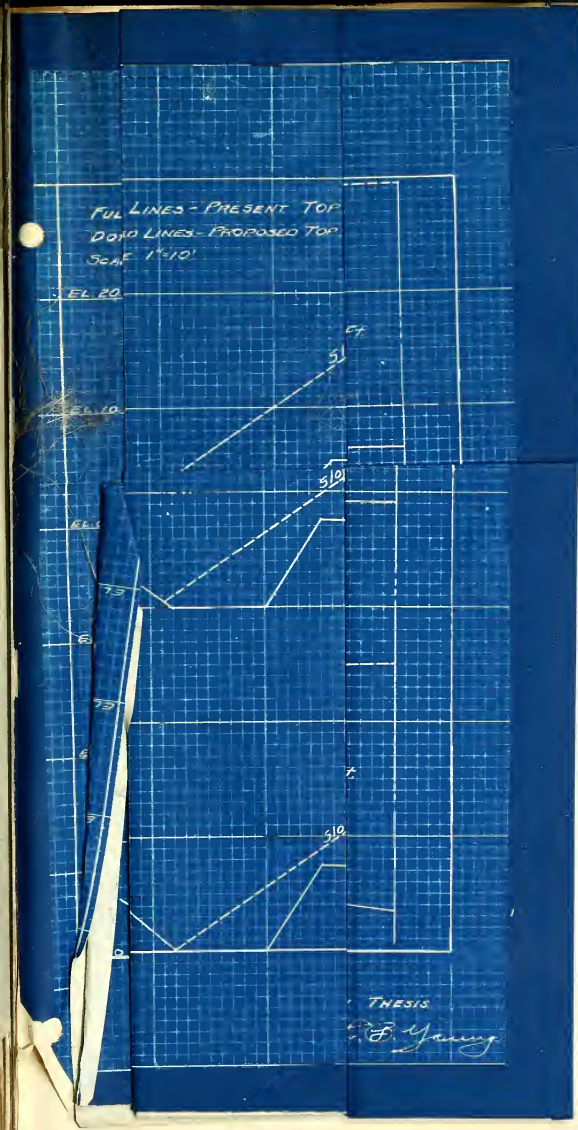

Full Lines: Profiles for 12" Manhole
Dotted Lines: Profiles for 8" Pipe Sewer
Scale 1"=10'
STA. 39+00
STA. 42+00
STA. 45+00
STA. 48+00
STA. 51+00
STA. 54+00


Slope 1:1
Slope 1:1
Slope 1:1




-PRESENT TOP
ES - PROPOSED TOP
Slope 1½
Level




FULL LINES = PRESENT TOP
DOTTED LINES = PROPOSED TOP
SCALE 1"=10'
EL. 20
EL. 10
51
510
510
THESIS

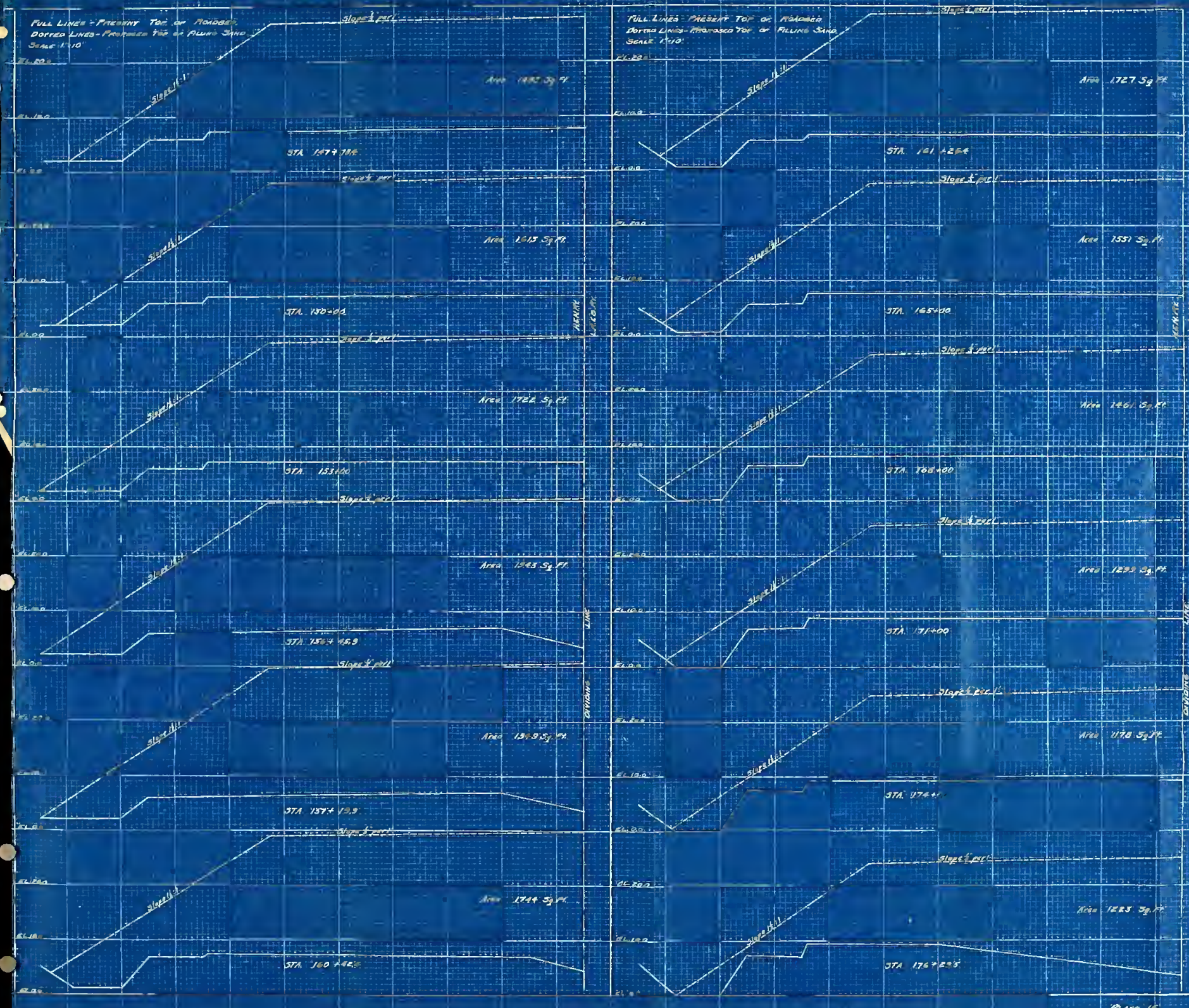


PLATE 16
SUBMITTED WITH THESIS
Wm. Newman Jr.
F. B. Young